STRUCTURES DESIGN MANUAL
TABLE OF CONTENTS:

SECTION 3 – GENERAL DESIGN & LOCATION FEATURES

3. GENERAL DESIGN AND LOCATION FEATURES

The design of a structure is separated into two distinct phases: (1) Preliminary Design, and (2) Final Design. The design effort required for a specific structure during each design phase is dependent upon whether the structure is a bridge, bridge rehabilitation, box culvert or other minor structure, and upon the structure's complexity. Some minor structures, such as overhead sign structures, have little or no preliminary design – the entire design is typically completed during the final design phase. For proprietary structures, such as multi-plate arches, three-sided precast concrete structures, and MSE walls, the designer prepares situation and layout plans (preliminary design) and the supplier or fabricator completes the final design during the construction phase. Review of the supplier's final design occurs during the construction phase.

During the preliminary design phase, the designer determines the primary structure geometry, the structure type, the general appearance and aesthetics, and the structure's relationship to surrounding project elements. The preliminary design phase also includes concept and scoping activities and the development of the Situation and Layout plans. The Situation and Layout plans define the general layout of the structure and serve as the basis for the final design.

During the final design phase, complete details for all structure elements are developed and presented in the structure plan set. These details include material descriptions, quantities, and geometric information. The final design plans and specifications include all necessary information required by the Contractor to construct the structure.

This chapter includes information that is general to both design phases, specifically the general design and layout. It supplements the requirements in Section 2 of the AASHTO *LRFD Bridge Design Specifications*. Guidance for the design of specific structural types or elements is provided in subsequent chapters of this manual. Information on the preparation and assembly of plans for a project (including plan content, organization, etc.) is included in *Guidelines for Preparing Structure Plans*. [Available in a future release.] Drafting standards are defined in Chapter 15 – Detailing Practice.

3.1 DEFINITIONS AND TERMINOLOGY

3.1.1 DEFINITIONS

The following definitions are based upon definitions in the UDOT 2005 Standard Specifications for Road and Bridge Construction, the AASHTO LRFD Bridge Design Specifications, and the NBIS Section of the Federal Register.

Bridge – A structure, including supports, erected over a depression or an obstruction such as water, highway, or railway, and having:

1. A track or passageway for carrying traffic or other moving loads,
2. An opening measured along the center of roadway of more than 20 ft between undercopings of abutments or springlines of arches, or extreme ends of openings for multiple boxes; it

may also include multiple pipes where the clear distance between openings is less than half of the smaller contiguous opening. (UDOT Std Specs; NBIS Section of Federal Register)

Bridge Length – The over-all length of a bridge measured along the line of survey stationing back to back of backwalls of abutments, if present, otherwise end to end of the bridge floor; but in no case less than the total clear opening of the structure.

Bridge Roadway Width – The clear width measured at right angles to the longitudinal centerline of the bridge between the bottom of curbs or in the case of multiple height of curbs, between the bottoms of the lower risers or if curbs are not used, between inner faces of parapet or railing.

Crossing Angle – The angle measured to the right while looking ahead (station-wise) between the survey or control line of the structure alignment and the survey or control line of the feature crossed. If one or both of the alignments involve a horizontal curve, it is measured to a line tangent to the curve at the point of intersection.

Culvert – Any structure that provides an opening under the roadway not meeting the classification of a bridge as defined in this section.

Load Rating – The determination of the live load carrying capacity of a bridge using bridge plans and supplemented by information gathered from a field inspection.

Plans – Approved contract drawings showing the location, type, dimensions and details of the Contract to be performed.

Standard Plans – Detailed drawings approved for repetitive use by the Department.

Structures Standard Details – Structure details approved for repetitive use by the Structures Division.

Working Drawings – Supplemental design sheets or similar data that the Contractor is required to submit to the Engineer such as shop drawings, erection plans, falsework plans, framework plans, cofferdam plans, and bending diagrams for reinforcing steel.

Scour – Erosion of streambed or bank material due to flowing water; often considered as being localized around piers and abutments of bridges.

Roadway – The portion of a highway within limits of construction.

Shoulder – The portion of the roadway adjacent to the traveled way where vehicles may stop for emergencies, and which supports base and surface courses.

Sidewalk – That portion of the roadway constructed for pedestrian use.

Skew angle – The angle between the alignment crossed and a line normal to the alignment carried by the structure. A crossing angle less than 90 degrees equates to a left skew. A crossing angle greater than 90 degrees equates to a right skew.

Specifications – The compilation of provisions and requirements for the performance of prescribed work.

> **Special Provisions** – A unique specification or a modification or revision to the standard specifications applicable to an individual contract.
>
> **Supplemental Specifications** – Approved additions and revisions to the Standard Specifications.
>
> **Standard Specifications** – Specifications approved for general application and repetitive use.

Structures – Bridges, culverts, catch basins, drop inlets, retaining walls, cribbing manholes, endwalls, buildings, sewers, service pipes, underdrains, foundation drains and other such features that may be encountered in the work. (Drop the "s"'s)

> **Major Structure** – A structure that meets the definition of a bridge.
>
> **Minor Structure** – A structure that does not meet the definition of a bridge.

Substructure – All of the structure below the bearings of simple and continuous spans, skewbacks of arches and tops of footings or rigid frames; including backwalls, wingwalls and wing protection railings.

Superstructure – All of that part of the structure except the substructure as defined in this Section.

Traveled Way – The portion of the roadway designated for the movement of vehicles, excluding shoulders and auxiliary lanes.

Utility – All privately, publicly or cooperatively owned lines, facilities and systems for producing, transmitting or distributing communications, power, heat, gas, oil, water, waste, storm water not connected with the highway drainage, signal systems and other products that directly or indirectly serve the public; the utility company.

Overhead Sign Structure – A structure that suspends a sign above the roadway.

Retaining Wall – A structure whose primary purpose is to retain earth.

3.1.2 BRIDGE ELEMENTS

[Future Addition]

3.1.3 TERMINOLOGY

[Future Addition]

3.2 STRUCTURE IDENTIFICATION

3.2.1 STRUCTURE NUMBER

The UDOT Structures Division assigns a unique **Structure Number** to each publicly owned, permanent structure for which plans are prepared. The structure number is the primary means of identification for the structure and never changes throughout its life. New structure numbers are requested by the Designer through the UDOT Structures web-site. [http://www.udot.utah.gov/index.php/m=c/tid=277]

When a structure is replaced, a new structure number is assigned to the new structure. The records of the demolished structure remain in the bridge inventory database for historical purposes; therefore, the structure number of a demolished structure is never reused.

When a structure is repaired or modified, it retains its existing structure number. A new structure drawing number is requested to differentiate the new plan set from the original plan set.

A. UDOT-OWNED STRUCTURES

For a UDOT-owned structure, the structure number consists of a letter (identifying the structure type) followed by a unique number; for example, C-123.

The structure type designations used in the structure number are as follows:

STRUCTURE TYPE DESIGNATIONS	
DESIGNATION	STRUCTURE TYPE
A	Timber Bridge Superstructure
B	Not used
C	Structural Steel Girder Superstructure
D	Cast-in-Place Concrete Superstructure Concrete Rigid Frame Structures
E	Concrete Box Culvert
F	Prestressed Concrete Girder Superstructure

STRUCTURE TYPE DESIGNATIONS	
DESIGNATION	**STRUCTURE TYPE**
G	Overhead Sign Structure
H	Concrete Headwall
P	Post-tensioned Concrete Superstructure
R	Retaining Wall (cast-in-place concrete, MSE, Soil Nail, masonry block, etc.);
V	Miscellaneous Structure Miscellaneous Drainage Structure Multi-Plate Steel Arch Structure Concrete Arch Drainage Structure Tunnel

B. STRUCTURES OWNED BY LOCAL GOVERNMENTS

For city- or county-owned bridges, the structure number consists of a three-digit county number, followed by the number of the bridge within the county, and the structure type designation letter; for example, 013100F.

The three-digit county numbers are as follows:

COUNTY NUMBERS					
NUMBER	**COUNTY**	**NUMBER**	**COUNTY**	**NUMBER**	**COUNTY**
001	Beaver	021	Iron	041	Sevier
003	Box Elder	023	Juab	043	Summit
005	Cache	025	Kane	045	Tooele
007	Carbon	027	Millard	047	Uintah
009	Daggett	029	Morgan	049	Utah
011	Davis	031	Piute	051	Wasatch
013	Duchesne	033	Rich	053	Washington
015	Emery	035	Salt Lake	055	Wayne
017	Garfield	037	San Juan	057	Weber
019	Grand	039	Sanpete		

When a project includes several retaining walls, all retaining walls of the same type (concrete cantilever, MSE single stage, MSE two-stage, MSE block, etc.) may be grouped together using the same general structure number (R-123) provided that a letter designation is added to the end of the structure number to distinguish each individual retaining wall (R-123A, R-123B, etc.). Use one plan set for all of the retaining walls grouped under a single structure number. Provide a Location

Plan showing all retaining walls covered by the general structure number (R-123) on the first sheet of the plan set with (general notes, quantities, etc.) followed by the details of each individual retaining wall.

Similarly, when a project includes several overhead sign structures, overhead sign structures of the same type (single cantilever, double cantilever, single mast span, double mast span, ATMS span, ATMS cantilever, etc.) may be grouped together using the same general structure number (G-123) provided that a letter designation is added to the end of the structure number to distinguish each individual overhead sign structure (G-123A, G-123B, etc.). Organize overhead sign structure plans the same as retaining wall plans.

For more information on organizing structure plans, refer to Section 15 – Detailing Practice and *Guidelines for Preparing Structure Plans*.

C. STRUCTURE NUMBER PLACEMENT

The structure number (not the drawing number, when different) is placed on the constructed structure either by permanently casting it into a structural concrete member or by some other method as detailed in the UDOT Structures standard details.

Place the structure number on the structure according to the following table:

STRUCTURE NUMBER (SN) LOCATION			
STRUCTURE TYPE	**LOCATION**	**ATTACHMENT**	**COMMENTS**
Bridge	Right Approach Parapet	Cast into concrete	Two-way bridges require SN placement at two locations
Concrete Drainage Structures (Includes 3-sided precast structures)	Top and exposed face of Headwall (2 places, each headwall)	Cast into concrete	Center on headwall facing away from box opening
Pedestrian Bridge	Support adjacent to outside shoulder	Cast into concrete	
Overhead Sign Structure	Near top of foundation	Cast into concrete	
Retaining Wall	N/A	N/A	Structure Number not currently placed on retaining walls
Concrete Arch Drainage	Headwall or End Beam	Cast into concrete	Center on headwall facing away from drainage opening
Structural Steel Multi-Plate Arch	Top of headwall or End Beam / Coping	Cast into concrete	Center on headwall facing away from drainage opening

** Cast the structure number into the bridge element. Do not use the structure drawing number if it is different than structure number.*

Refer to UDOT standard details for the exact size and location to place the structure number for each structure type.

Structural supports for high mast lighting, traffic signals, camera poles, etc. though designed as structures are not given a structure number by the Structures Division. They are numbered and inventoried by the UDOT Traffic and Safety Division. This also applies to standardized structures constructed according to UDOT standard drawings.

D. UDOT STRUCTURES INVENTORY

When working with the UDOT Structures inventory database, it is necessary to note that, for bridges, the database and associated programs add to the structure number an additional number that indicates the direction of traffic on the bridge; ie, nC-123, where "n" defines the direction of traffic as outlined in the following table:

Designation	Direction of Traffic
0	Two-directional
1	North
2	East
3	South
4	West

The Direction of Traffic Designation is based upon the roadway direction (the direction of ascending mile posting), not the actual compass direction. For instance, US 40 is an east–west roadway, but near Park City it runs north–south. The Direction of traffic designation for the entire length of US 40 is based upon an east–west direction, even though portions run north–south.

This modified bridge number appears on any reports prepared by the Bridge Management System, PONTIS, etc. such as the Structures Inventory and Appraisal (SI&A) report. It does not appear on the structure plans.

3.2.2 STRUCTURE DRAWING NUMBER

The UDOT Structures Division assigns to each structure plan set a unique **Structure Drawing Number**. The structure drawing number is the primary means of identifying the structure plan set. Structure drawing numbers are requested by the Designer through the UDOT Structures web-site.

For new structures, the structure drawing number is the structure number.

For a modification of an existing structure, the structure drawing number modifies the existing structure number.

- For bridge and box culvert widenings, the structure drawing number adds a “W” to the end of the existing structure number (Examples: C-123W; E-1234W).
- For a bridge rehabilitation, the structure drawing number adds ”R” to the end of the existing structure number. When a bridge is rehabilitated multiple times, the structure drawing number adds “Rn” to the end of the existing structure number where “n” is the number of times the bridge has been rehabilitated. (Examples: Original plans = C-123; 1st rehabilition project = C-123R; 2nd rehabilitation project = C-123R2, 3rd rehabilitation project = C-123R3, etc.)
- For projects that include the rehabilitation of multiple bridges with similar details, details for all bridges may be combined into one plan set with one structure drawing number. In this case, the structure drawing number is M-nnn, where “M” denotes a plan set that includes details for multiple structures and “nnn” is a unique three-digit number.
- For the extension of an existing box culvert, the structure drawing number adds “En” before the structure type designation of the existing structure number, where “n” is the number of times the box culvert has been extended.

Structure drawing numbers are assigned according to the information in the following table:

Type	Structure Number	Structure Drawing No.		
		Modification	Example	
New Bridge	C-123	N/A	C-123	
Bridge Widening	C-123	Add “W” after number	C-123W	
Bridge Rehabilitation	C-123	Add “Rn” after number	C-123R; C-123R2, C-123R3, etc.	“n” = the number of times rehabilitated
Box Culvert Widening	E-1234	Add “W” after number	E-1234W	
Box Culvert Extension	E-1234	Add “En” before type designation	E1E-1234; E2E-1234, etc.	“n” = the number of times extended
Overhead Sign Structures	G-123A, G-123B, etc.	Combine individual signs of the same type on the same project into one plan set	G-123	
Rehabilitation of Multiple Bridges in one plan set	Various	M-nnn	M-123	“nnn” = unique three-digit number

3.2.3 Structure Name

The structure name is a description of the bridge crossing and includes the name of the feature carried and the feature crossed. A few examples of structure names include: "US 40 over Silver Creek and UPRR," "10600 South over I-15," "I-70 over the Colorado River," etc. The structure name should give a clear description of the bridge. In some cases, the structure name may need to be abbreviated to fit within the title block of the plan sheets.

3.3 Geometrics

3.3.1 General Criteria

The bridge width and the typical section of the roadway(s) crossed are determined by the classification and geometrics of the feature(s) carried by the bridge and the feature(s) crossed. The geometrics of the approaching roadway are to be carried over and under the bridge to the maximum extent practicable.

The bridge geometry and layout are based upon the roadway geometrics provided by the roadway designer to the bridge designer. The roadway geometry is determined by roadway classification and is based upon AASHTO and UDOT standards. UDOT Standard Drawings DD-8, DD-9, and DD-10 specify bridge geometry requirements for the cross-sections of the bridge roadway and the feature(s) crossed. Consult and apply the requirements on these drawings when laying out bridges. Provide the preferred clearances shown on the standard drawings, unless approved by the Deputy Bridge Engineer for Design. Where geometric constraints prevent using the preferred clearance, provide the maximum clearances possible, but no less than the minimum clearances shown.

The roadway designer provides to the bridge designer the roadway geometry information necessary to lay out the bridge. It is the responsibility of the bridge designer to verify the correctness and consistency of the roadway information received and resolve any conflicts with UDOT standards before using it in the structure design. Refer to UDOT Standard Drawings DD-4, DD-11, DD-12 and DD-13 for roadway typical section information. See UDOT Standard Drawing DD-1 for superelevation information.

3.3.2 Alignment Geometry

Good bridge geometric design is intrinsic to the development of aesthetic, economic, safe and efficient structures. Bridge geometry and appearance are defined by the alignment geometry. No amount of aesthetic treatment can correct for undesirable bridge geometry. When beginning the bridge layout, evaluate the alignment geometry provided by the roadway designer.

Consider the following when evaluating alignment geometry in the vicinity of a bridge:

- Verify that the alignment profiles provide adequate vertical clearance and structure depth for the selected bridge type.
- Locate any spiral curves and other complex geometry so that they are completely outside of the bridge limits (including approach slabs).
- Design superelevation transitions within the bridge limits such that the entire cross-section rotates as a unit. If this cannot be done, a longitudinal construction joint is required at the point of rotation.
- Minimize the bridge skew to provide simpler and more efficient design and construction. As the skew increases, bridge span lengths and the overall bridge length increase as well.
- It is recommended that the skew of bridge supports be limited to 30 degrees. Supports skewed greater than 45 degrees significantly complicate the bridge design and construction, and affect the bridge aesthetics. Skews greater than 45 degrees require the approval of the Deputy Bridge Engineer for Design.
- Avoid skewed supports on horizontally curved bridges. Design horizontally curved bridges with radial supports.
- Provide a minimum profile grade of 0.5% on the bridge to accommodate longitudinal drainage.
- Very flat vertical curves require special attention to ensure that the bridge deck will drain properly. Flat profile grades combined with superelevation transitions may create low spots.
- Evaluate multi-span bridges with steep profile grades that cross multiple alignments to balance clearances.
- Evaluate bridge deck elevation contours to prevent low spots.
- Balance span lengths as much as possible.
- Provide adequate clearance to bridge supports
- Ensure that horizontal and vertical alignments accommodate the selected bridge type.
- Evaluate the horizontal and vertical alignments to ensure that they do not unduly complicate the bridge design and construction.

3.3.3 BRIDGE SUPERSTRUCTURE GEOMETRY

A. BRIDGE WIDTH

Design the bridge width to comply with UDOT Standard Drawing DD-9. Always add 2 ft. to the roadway shoulder width for shy distance. Generally, the bridge width should match the width of the approaching roadway. Reducing the roadway width at a bridge creates a bottleneck and is not allowed.

Where a bridge includes a median parapet, provide a longitudinal joint in the center of the median parapet and separate the cross-section into two separate bridges.

For bridges that require a median parapet and for bridges with roadway widths greater than 100 ft, use two separate bridges with separate median parapets. Provide a minimum gap of 2-inches between the bridges to allow for independent seismic movement. Increase the gap width for longer, more flexible bridges where transverse movements will exceed 2-inches. Only use a longitudinal bridge deck joint where there is a median parapet and the bridge can be separated into two individual bridges.

Where the bridge geometry permits the use of prestressed concrete girders on a bridge with a horizontally curved alignment, or in other situations that permit using straight girders on horizontally curved alignments, use the following criteria to determine when straight girders may be used:

- For curve offsets (between supports) equal to 12-inches or less: Use straight girders and widen the bridge to eliminate a curved edge of deck.
- For curve offsets (between supports) greater than 12-inches and equal to or less than 24-inches: Use straight girders and curved edges of deck.
- For curve offsets (between supports) greater than 24-inches: Use curved girders and curved edges of deck.
- Curved bridges with curve offsets greater than 2-ft require economic and aesthetic evaluation and the approval of the Deputy Bridge Engineer for Design before straight girders may be used.
- In all cases, comply with minimum and maximum deck overhang requirements. In no case shall the distance between the edge of deck and the girder top flange be less than 2-ft.

Use horizontally-curved girders for all curved bridges that use steel girders.

For bridges with tapers, begin and end tapers at a support (bent or abutment), or continue it across the entire length of the bridge. Extra width to eliminate or simplify a taper or curvature is permissible where it is justified by simplifying design and construction.

When determining the cross-section of new structures, consider provisions for deck replacement. Where there are no readily accessible alternate routes and the bridge cannot be closed, the deck must be replaced in phases and the superstructure cross-section must allow for phased construction. Consider in the design the minimum phasing widths and the necessary girder support for those widths. This may require increased width or an additional girder line. Consider overhang limitations when replacing decks originally designed using the empirical deck design method.

B. SHOULDERS ON AND UNDER BRIDGES

Roadway cross-sections that approach bridges will normally provide a clear zone recovery area next to the travel lane for the benefit of out-of-control vehicles. It is not economical or practical to carry the full clear zone widths across bridges. Standard widths for bridge shoulders have been set to balance costs and safety. Barriers and railings are typically located within the clear zone, are considered a hazard, and require protection in the bridge approach area.

Shoulders are essential to the proper function of the highway. They provide the following functions:

- Recovery area to regain control of a vehicle
- Emergency parking area for stalled vehicles and escape route for stranded motorists
- Passageway for bicycles and occasional pedestrians (on roadways that are not limited access and do not have a sidewalk)
- Passageway for emergency vehicles
- Parking area for bridge maintenance and inspection vehicles (such as the bridge inspection crane)
- Temporary traffic lane during deck repairs or overlay construction
- Area for deck drainage and snow storage
- On two-lane highways, the shoulders provide an escape area to avoid a head-on collision with an oncoming passing vehicle

C. SIDEWALKS ON BRIDGES

Use a minimum width of 6'-0 between back face of parapet or curb and fence (6'-8" to the edge of deck).

D. CROSS SLOPES ON BRIDGES

Cross-slopes on bridges are designed in compliance with UDOT Standard Drawing DD-01. The roadway designer provides the superelevation data to the bridge designer. The bridge designer validates the data received for compliance with the standard drawing and resolves any discrepancies with the roadway designer.

Superelevation Transitions: With most screed machines, it is not possible to transition one half of the bridge deck at a different rate than the other half without multiple placements (phased construction). For this reason, design all superelevation transitions on bridges (full length of bridge) such that the entire bridge cross-section between the ends of approach slabs transitions as a complete unit. In cases where a longitudinal construction joint is required in the deck, this requirement applies to each individual placement.

E. BRIDGE WIDENINGS

When widening a bridge, maintain design consistency with the existing bridge.

- Use the same or similar girder type and size for the new section(s) as was used in the existing bridge.
- Maintain the relative stiffness between the new and existing bridge sections. Design the widened superstructure sections to have similar stiffness to the existing superstructure

sections. This means matching the deck and girder type and sizes (for example, AASHTO Type V) and using a girder spacing as close to the existing as possible.
- Where possible, locate the longitudinal deck construction joints between the existing and new sections along the centerline of a girder.
- Make any widened sections of abutments and intermediate supports structurally and aesthetically consistent with the existing abutments and bents.
- Upgrade substandard shoulders, parapets, etc. to current standards.

F. PEDESTRIAN BRIDGES

Design pedestrian bridges in accordance with AASHTO *Guide Specifications for Design of Pedestrian Bridges*. Comply with all applicable requirements in the ADA *Accessibility Guidelines for Buildings and Facilities*. The following requirements apply to all pedestrian bridges to ensure that they are accessible, safe, and durable and comply with ADA guidelines.

- Standard width from face of handrail to face of handrail is 8'-0".
- Maximum grade is 8.33% (12:1). A grade flatter than the maximum is preferable. When the grade is steeper than 5%, provide a 5'-0" platform for each 2'-6" change in elevation.
- Provide a platform at each abrupt change in horizontal direction (minimum 5'-0" by 5'-0").
- Provide a 6'-0" minimum clear platform at the bottom of each ramp.
- Design the profile grade such that there are no abrupt grade breaks at expansion devices.
- Place a protective screening, preferably a chain link fence system or a railing system, on both sides of the bridge.
- The minimum height above the top of sidewalk is 8'-0". 10'-0 is preferred.
- Detail the rails as follows:
  - Minimum height for pedestrian railings is 3'-6".
  - Bicycle railings must be at least 4'-6" in height.
  - For pedestrian bridges over roadway, the opening between elements of a pedestrian railing shall not permit a 4" sphere to pass through.
  - For pedestrian bridge that are not over roadways, the opening between elements of a pedestrian railing shall not permit a 4" sphere to pass through the lower 27" of the railing. A 6" sphere shall not be able to pass through any opening above 27".
- Provide a cover plate over all pedestrian bridge expansion joint openings to protect pedestrians from a tripping hazard.
- When structural tubing is used, provide details that are watertight or designed such that moisture cannot be trapped in or on the member to accelerate corrosion.

3.3.4 BRIDGE PARAPETS AND RAILINGS

When parapets are used on bridges and approach slabs, use 42" high single-slope parapets unless approved otherwise by the Deputy Bridge Engineer for Design. Place any transitions between bridge parapets and roadway barriers on the roadway section, not on the approach slabs. Provide one three-inch and one 1-1/2 inch spare conduit in each outside parapet on all bridges.

On bridges that carry pedestrian traffic, provide fencing using details from the UDOT Structures Division's standard details and Standard Drawing FG-6 "Chain Link Fence." The fence may be upgraded on a project-by-project basis as determined by aesthetic requirements. A fence upgrade may also be granted when requested by a city or county. In this case, the city or county is responsible for the upgrade cost.

Protect the ends of bridge parapets within the clear zone from traffic impacts. For design speeds over 40 mph, a crash tested guardrail transition is required. If an attenuator is used, do not locate it on the bridge or the approach slab, unless there is no alternative.

Use a concrete parapet between the roadway and the sidewalk for design speeds greater than 40 mph. A raised sidewalk protected by curb and gutter may be used for design speeds of 40 mph or less. When curb and gutter is used, a concrete parapet meeting the AASHTO requirements for a combination traffic and pedestrian railing is required on the outside edge of sidewalk.

3.3.5 BRIDGE UNDERCROSSING GEOMETRICS

Design bridge undercrossing geometry in accordance with UDOT Standard Drawings DD-8, DD-9 and DD-10.

Limit the steepness of all fill slopes in front of abutments to 1.5:1 (H:V). Limit the steepness of cut slopes in front of abutments to 2:1 (H:V). Slopes beneath bridges require concrete slope protection, unless approved by the Deputy Bridge Engineer for Design. Refer to the guidelines for laying out concrete slope protection in Section 13.1.6 for the transitions and limits of concrete slope protection. For new bridges, place a one-foot level area between the top of slope and the front of the abutment to facilitate inspection access.

A. HORIZONTAL CLEARANCES

Provide horizontal clearances under bridges in accordance with UDOT Standard Drawing DD-8. Bridge underpass geometrics must rationalize safety requirements with costs and physical controls such as span length and permissible structure depth.

When the full preferred clearances cannot be provided, provide the greatest side clearances that circumstances will permit. A side clearance of 20 feet is not as desirable as 30 feet, but is still better than the absolute minimum clearance.

Eliminate intermediate supports from within the roadside clear zone area wherever possible. When intermediate supports cannot be eliminated from the clear zone area, provide roadside barrier to protect the support in its entirety.

Provide a minimum distance of one foot between the back face of fixed roadway barriers and structural elements such as bent caps, columns, abutments and retaining walls. Between the back face of non-fixed or flexible roadway barrier or guardrail and structural elements, provide a minimum distance of one foot plus the expected barrier or guardrail deflection, or two feet, whichever is greater. This does not supersede requirements in the AASHTO Bridge Design Specifications.

Drainage design along the highway crossed will affect the bridge span length. The typical section of the feature crossed should include drainage provisions through the bridge crossing. This will consist of ditches or piping.

B. VERTICAL CLEARANCES

Provide the following minimum vertical clearances:

- 16’-6” for all highway grade separations. When minimum clearance over the highway is the controlling factor, the minimum vertical clearance should not exceed 17’-0.
- 23’-6” for bridges over railroads (includes 6” for future ballast). When the minimum vertical clearance over the railroad is the controlling factor, the minimum vertical clearance should not exceed 24’-0.
- 17’-6” for stand-alone pedestrian overpass structures crossing highways.
- 8’-0” for structures over a walkway or sidewalk.
- 17’-6” for overhead sign structures including Variable Message Signs. The clearance is measured from the highest elevation of the roadway section to the lowest point on the sign panel (or to the support if it is within the required clearance envelope).
- Add an additional 1.00 ft to the minimum vertical clearance of all highway and railroad grade separations for non-redundant structural elements such as post-tensioned straddle bent caps;
- Design all structures over streams with a minimum freeboard clearance of 2’-0” between the low point on the bridge superstructure and the water surface elevation for Q_{50}. The minimum freeboard is required to allow for larger floods and the passage of debris through the bridge opening. Streams that carry more than usual amounts of debris may require greater freeboard clearance. Consult with the Hydraulic Engineer to determine if a freeboard clearance larger than standard is required.
    - The Deputy Bridge Engineer for Design may approve a freeboard less than specified on a case-by-case basis, as follows:
        - The bridge opening provides 2’-0 freeboard at Q_{50}, and the 0’-0 freeboard at Q_{100} (required by FEMA);
        - It can be shown that the stream or channel carries low amounts of debris.
    - On local government bridges, provide 2’-0 freeboard at Q_{25}.

When calculating the minimum vertical clearance for bridges with prestressed concrete beams, consider the bottom of the beam as a straight line between supports. This is because the girder is cast as a straight line. At full service load, the girder has minimal tension in the bottom fiber, which equates to a relatively straight profile. There may be some excess camber left in the girder, but there are too many variables to accurately predict girder camber during the design phase.

In urban areas, where girders are haunched over the median strip of an interstate highway and the median can accommodate additional traffic lanes, give consideration to maintaining 16’-6” minimum vertical clearance between the girder haunch and the future lanes. In computing this clearance, assume that the lateral slope of the interstate highway will be continued through each of the future lanes thus provided for, and through the shoulders adjacent thereto. Also assume that shoulder widths will remain unchanged for such future construction.

C. HIGHWAY CROSSINGS

Refer to UDOT Standard Drawing DD-8.

Verify the potential need for additional future lanes when using vertical abutments in highly urban areas. The use of vertical abutments (instead of spill-through slopes in front of the abutments) eliminates the possibility of adding future lanes to the facility crossed should traffic demands increase significantly.

D. WATERWAY CROSSINGS

For information on the hydrologic and hydraulic design requirements for bridges crossing streams and waterways, refer to the AASHTO *LRFD Bridge Design Specifications*, Subsections 2.3.1 and 2.6 (including commentary), the UDOT Roadway Drainage Manual, and the UDOT Hydraulics Manual.

E. RAILROAD CROSSINGS

UDOT Standard Drawing DD-10 defines the required clearances for bridges over railroads. In addition, provide the construction clearances shown on the railroad’s standard drawings. For bridges over UPRR tracks, meet the requirements of the Union Pacific Railroad’s, “Guidelines for Design of Highway Separation Structures over Railroad (Overhead Grade Separation).”

Comply with the pier protection requirements in AASHTO LRFD 3.6.5.2 and AREMA *Manual for Railway Engineering*, Volume 2, Chapter 8, Part 2, Section 2.1.5: Pier Protection. The AREMA requirements are repeated here to facilitate ease of use.

2.1.1 Pier Protection

2.1.1.1 Adjacent to Railroad Tracks

a. To limit damage by the redirection and deflection of railroad equipment, piers supporting bridges over railways and with a clear distance of less than 25 feet from the centerline of a railroad track shall be of heavy construction (defined below) or shall be protected by a reinforced concrete crash wall. Crash walls for piers from 12 to 25 feet clear from the centerline of track shall have a minimum height of 6 feet above the top of rail. Piers less than 12 feet clear from the centerline of track shall have a minimum crash wall height of 12 feet above the top of rail.

b. The crash wall shall be at least 2'-6" thick and at least 12 feet long. When two or more columns compose a pier, the crash wall shall connect the columns and extend at least 1 foot beyond the outermost columns parallel to the track. The crash wall shall be anchored to the footings and columns, if applicable, with adequate reinforcing steel and shall extend to at least 4 feet below the lowest surrounding grade.

c. Piers shall be considered of heavy construction if they have a cross-sectional area equal to or greater than that required for the crash wall and the larger of its dimensions is parallel to the track.

d. Consideration may be given to providing protection for bridge piers over 25 feet from the centerline of track as conditions warrant. In making this determination, account shall be taken of such factors as horizontal and vertical alignment of the track, embankment height, and an assessment of the consequences of serious damage in the case of a collision.

F. CONSTRUCTION CLEARANCES

Provide horizontal and vertical clearances during all phases of construction. For example, if the roadway crossed will be lowered after bridge girders are erected and will carry live traffic prior to being lowered, provide the minimum clearances based upon the higher roadway. The Deputy Bridge Engineer for Design must approve any exceptions to this requirement.

When locating intermediate supports during preliminary design, consider forming and shoring clearances to highways and railroads.

3.4 BRIDGE AESTHETICS

"The modern bridge designer must bring to his understanding of structural design and functional values a strong feeling for beauty of line, form and proportion. If he does not give his heart and his mind

to making his works beautiful, he is betraying a moral obligation and a civic trust."

-- D. B. Steinman

3.4.1 The Importance of Bridge Aesthetics

Aesthetic design is an integral part of all bridge designs. It is initiated at the very beginning of the structure layout. Bridge aesthetics is inherent in the structure type, size and shape. Appropriate aesthetic design cannot be an afterthought. It is not ornamentation. Aesthetic decisions made (or not made) early in the design process most likely will not be able to be changed later in the process because of schedule and budget requirements. For this reason, there must be an appropriate emphasis on aesthetics early in the design process.

All bridges make an aesthetic impact. A bridge has a strong visual impact in any landscape. A bridge may become a central element in a community, even though it is a simple crossing. Steps must be taken to assure that even the most basic structure will complement rather than detract from its surroundings.

The Bridge Design Engineer is responsible for the aesthetic impact of his/her bridge. Once constructed, a bridge is expected to remain in place for 75 years or longer. All who view the bridge will view the result of the engineer's design efforts. Engineers should consider good appearance co-equal with strength, safety and cost.

All bridges must be consistent with their surroundings, including other bridges in the vicinity. When designing a new bridge in an area with one or more existing bridges, consistency of bridge type and detail with the existing bridge(s) is critical.

There is a cost to the Department for poor aesthetics and a reward for good aesthetics. The cost or reward adds to or takes away from the trust placed in the Department by the public and other stakeholders. The public expects transportation facilities that are economical, safe, durable (long lasting), and with good appearance.

If proper attention is given to bridge aesthetics from the beginning, an aesthetic bridge need not cost more than an unattractive bridge. Bridges that are well-proportioned structurally using the least material possible are generally well-proportioned visually. Also, spending a little more time during the design phase selecting the most appropriate structure type could lead to significant construction savings.

3.4.2 The Ten Determinants of Appearance

In his book *Bridgescape: The Art of Designing Bridges*, Frederick Gottemoeller proposes that there are 10 determinants of appearance in bridge design. He writes: *"How people react to a bridge depends on what they see first, followed by whatever additional features they notice, in the order that they notice them. First impressions are rarely completely overridden by later information.*

People see the big elements first, the structural elements. Thus, the shapes of the structural elements are the most important in determining our reaction to a bridge. Color of the big elements is next; then, if time and distance permit, the details and their colors and textures. It follows that the 10 determinants of a bridge's appearance are ordered in importance by their influence on the shapes of the structural elements."

The 10 determinants of appearance (according to Gottemoeller) are included here to assist the bridge designer in developing an aesthetic design. They are listed in order of importance and are as follows:

1. ***Vertical and Horizontal Geometry*** – *The alignment geometry establishes a ribbon in space that will be attractive or unattractive. It determines how high the structure is, whether it is curved in one or two planes, how the roadway widens and splits, and how it is positioned relative to prominent surrounding features. The geometry establishes the basic lines of the structure, to which all else must react. A graceful geometry will go a long way toward guaranteeing a successful bridge, while an awkward or kinked geometry will be very difficult to overcome with later decisions.*

   Bridge engineers are often handed the geometry as a predetermined element. They must reserve the right to evaluate it and request changes if necessary to improve the appearance of the structure.

2. ***Superstructure Type*** – *The superstructure type establishes the overall shape of the structure, which is the most memorable aspect of the structure. It defines whether the structure is an arch, girder, rigid frame, truss, or cable-supported.*

3. ***Pier Placement*** – *Establishes not only the points at which the structure contacts the topography but also the size of the openings framed by the piers and superstructure. The success of the visual relationship between the structure and its surrounding topography will depend heavily on the apparent logic of the pier placement. For example, a pier near a water edge will appear more logical if placed on the shore side of the boundary.*

4. ***Abutment Placement and Height*** – *Determines how the bridge starts and ends and, for shorter bridges, how the structure is framed. The abutment placement also establishes the shape of the end-span opening, which can have a significant influence on what can be seen beyond the structure, and how well the structure relates to adjoining uses.*

5. ***Superstructure Shape*** – *Establishes the form of the structural members, including deck overhangs, parapets and railings. This is the point at which the structure can be shaped to respond to the forces on it. The intrinsic interest of the structure will be determined by this characteristic.*

6. ***Pier Shape*** – *Defines the form and details of the piers. From many viewpoints, particularly at oblique angles to the structure, the shapes of the piers will be a major influence on the impression created.*

7. ***Abutment Shape** – Defines the form and details of the abutments. For shorter structures, and from viewpoints near the ends of longer structures, the shape and detail of the abutment will be important. For structures involving pedestrians, the provisions made for them at the ends of the bridge can be among the most memorable aspects of the structure.*

8. ***Color** – The colors of uncoated structural materials as well as the coated elements and the details. Color, or lack of color, will influence the effect of all the decisions that have gone before. It provides an economical opportunity to add an additional level of interest.*

9. ***Other Bridge Details, Surface Textures, and Ornamentation** – Establishes elements that can add interest and emphasis. Structural elements, such as stiffeners and bearings, can serve this function. Traditional systems of architectural ornament started from a desire to visually emphasize points where force is transferred, such as from beam to column through an ornamental capital. Patterns of grooves or insets and similar details added to make an element seem thinner are other examples.*

10. ***Signing, Lighting, and Landscaping** – Though not actually part of the structural system, these elements can have great influence on the aesthetic impression a bridge makes.*

Gottemoeller continues: *"Decisions about the first five determinants are usually thought of as strictly "engineering" decisions. However, they are inescapably aesthetic decisions as well. Decisions on determinants 6 through 9 are the ones most often thought about when speaking of "bridge aesthetics," but it is almost impossible for decisions made about these elements to completely compensate for poor decisions made about the first five. A poorly shaped girder cannot be corrected by painting it an attractive color. Make the best possible decision about the first five elements, and then use elements 6 through 9 to accentuate and improve the positive qualities that have been created."* (Frederick Gottemoeller, *Bridgescape: The Art of Designing Bridges*, pp. 55-58.)

3.4.3 REFERENCES

Engineers are not typically trained in aesthetic principles and may not understand how to create an aesthetic bridge. Educating oneself in aesthetic principles can take a significant amount of effort. To facilitate this process, UDOT Bridge Design Section will develop bridge aesthetic design guidelines to assist designers with bridge-related aesthetic principles and details. Until that time, designers may find the following references helpful:

1. AASHTO *LRFD Bridge Design Specifications*, Subsection 2.5.5. This section provides some very good information and detail on bridge aesthetic requirements. It is hoped that bridge designers will refer to it often.
2. Frederick Gottemoeller, *Bridgescape: The Art of Designing Bridges*, John Wiley & Sons, Inc. 2004
3. NRC, *Bridge Aesthetics Around the World*, Transportation Research Board, National Research Council, Washington, D.C., 1991
4. Maryland DOT, *Aesthetic Bridges Users Guide*, 2005

5. Minnesota DOT, *Aesthetic Guidelines for Bridge Design*, 1995

3.5 Preliminary Bridge Plans

3.5.1 General

Preliminary bridge plans document the main features of the bridge (type, size, location, aesthetics, etc.) and are used to obtain approvals and coordinate the preliminary design between design disciplines before the final design begins. They also enable the designer to more accurately define the cost and scope of the work. Preliminary bridge plans consist of the Situation and Layout plan sheets and accompanying design reports as outlined in this section and Section 2 – UDOT Structures Design Quality Plan. Approval of Situation and Layout plans is required for all new bridges, bridge widenings, box culvert drainage structures, and retaining walls before final design can begin. The situation and layout plans for other minor structures are generated during the final design process. Approved Situation and Layout plans are used as the basis for the bridge final design and for the preparation of final detailed plans.

To facilitate preliminary and final design approvals, the designer should identify early in the process any structure-related environmental requirements and commitments, and incorporate them into the preliminary bridge plans.

Detail the bridge situation and layout sheets in accordance with the Situation and Layout Detailing Checklist. Additional information on the content and organization of preliminary bridge plans are included in Section 15 – Detailing Practice and *Guidelines for the Preparation of Structure Plans*.

Unusual bridges and structures on the interstate system are subject to review by the FHWA Headquarters Division in Washington DC for review. For more information on this submittal and what constitutes an unusual bridge, refer to Section 1.4.4 of this manual.

3.5.2 Concept and Scoping

[To be added later.]

3.5.3 Bridge Type Selection

The structure type and span arrangement is dictated by cost, aesthetics, depth available, geometrics, and site conditions. For some bridges, this may be an obvious choice. For others, it may involve significant evaluation. The following gives some general bridge type selection guidelines.

A. STRUCTURE TYPE

It is the responsibility of the Designer to use the most appropriate and economical structure type at each structure location. At times, this requires innovation and ingenuity to provide a structure type that best meets the project characteristics and needs. There are many factors that dictate what the correct structure type should be. Among these are the following: Economics (cost), Environmental Conditions, Geometry, Span length and arrangement as determined by features crossed, Safety, Aesthetics, Location and setting, Construction schedule, Traffic impacts, etc.

The Department traditionally uses the following major bridge types due to their advantages and cost-effectiveness:

- Prestressed concrete I-girders with a cast-in-place concrete deck.
- Structural steel I-girders with a cast-in-place concrete deck.
- Cast-In-Place or Precast Concrete Box Culvert

These bridge types are not the only bridge types that are acceptable for use on UDOT projects. Other bridge types may be used if it can be shown that they are better suited to the project-specific criteria and to Utah's unique environment. The UDOT Bridge Section's philosophy is to use innovative and forward-thinking solutions, but these solutions should also be successfully implemented by other state DOT's and must meet the Department's goals of low maintenance and long-term durability when subjected to Utah's unique environmental conditions before they will be approved for use on UDOT projects.

Experimental bridge types, timber bridges and masonry bridges are typically not used. For the Department to consider using bridge types other than those listed, the proposer must supply information early in the concept or preliminary design process that demonstrates the following:

- The bridge type is accepted for general use by other transportation authorities. Include Project contact information.
- The bridge type and components will perform well under the environmental conditions of the Project, including frequent freeze-thaw cycles, heavy road salt use and high seismic events.
- Justification for why the proposed alternate bridge type is the best solution for the project.
- The bridge type allows for the deck to be completely removed and replaced with minimal impact to cross-traffic and bridge traffic.
- A life cycle cost analysis with comparison to a traditional bridge type.

(1) Prestressed Concrete Beams

In the absence of design constraints, the use of AASHTO prestressed concrete beams provides the most economical and maintenance free bridge structure up to 140 ft span length. Other more efficient bulb-tee prestressed concrete girders (such as the Wasatch I-15 girders) may extend that limit up to 165 ft.

The advantages of prestressed concrete girder bridges include the following:
- Low initial and future maintenance costs,
- High quality factory produced product,
- A stiff superstructure, and
- Simpler erection.

Disadvantages include:
- Beams are limited to standard depths
- Beams are limited to straight segments
- Limited span length

(2) Structural Steel Plate Girders

When design constraints prevent the use of prestressed concrete beams (i.e., curved horizontal alignment, inadequate vertical clearance, bridge spans exceeding the limits of prestressed concrete beams, etc.), use structural steel welded plate girders as a second choice.

The advantages of structural steel plate girder bridges include:
- Well suited to complex urban freeways with limited depth, long spans, and complex geometrics
- Well suited for sites with poor soil conditions
- Shallower structure depth than prestressed concrete beams,
- Allows girder field splices
- Web plates that can be cut to any depth or to a haunched shape,
- Allows for horizontal curvature
- More flexible structure type compared to concrete structures.

Disadvantages include:
- Higher cost than prestressed concrete
- More difficult fabrication and inspection
- More complicated erection
- Currently, longer lead time for obtaining material
- Longer fabrication time
- Requires initial painting and future maintenance painting
- Potential for rusting and fatigue cracking

(3) Additional Requirements

Designers should also consider the following requirements when determining the appropriate bridge type:

- Rolled steel beam sections may be used where necessary in shorter spans, but the use of cover plates is not permitted.
- The Department uses large quantities of salt and de-icing chemicals in the winter, which accelerate the corrosion of bridge structures. The bridge type and materials must address this concern.
- Incorporate as few deck expansion joints as possible.
- Make bridges continuous over supports, and use integral or semi-integral abutments wherever possible.
- When expansion joints are required, locate them at supports.
- Do not use pin and hanger details at expansion joints unless approved by the Deputy Bridge Engineer for Design.
- Space girders so that the moments in exterior girders will not be larger than the moments in interior girders.
- Comply with the span-to-depth ratio requirements in AASHTO LRFD 2.5.2.6.3.

In the future, this section will be expanded to address the following:

- Precast deck elements,
- Rapid construction techniques,
- Special cases
- Box culverts
- Multi-plate arches
- Precast concrete culvert structures
- Three-sided precast concrete structures

B. ABUTMENT AND BENT LOCATIONS

(1) Highway Grade Separations –

For grade separation bridges it is desirable to minimize the number of bents, wherever practical. Do not place bents in the clear zone unless absolutely necessary. In locations where ramps enter or exit a highway under a bridge, avoid placing intermediate supports between the mainline and the ramp as they restrict visibility. Intermediate supports located within 30 feet of the edge of roadway must be designed for an equivalent static force of 400 kips as outlined in AASHTO *LRFD Bridge Design Specifications* 3.6.5.2 unless it is protected as specified in AASHTO *LRFD* 3.6.5.1.

(2) Railroad Grade Separations

For bridges over railroads, bents located within 25 feet of the centerline of railroad tracks must either be of "heavy construction" or have crash walls (see Section 3.3.5 E). Bents located between 25 feet and 50 feet of the centerline of railroad tracks must be designed to withstand a 400 kip load unless they are protected as specified in LRFD 3.6.5.1.

(3) Stream Crossings –
For stream crossings, minimize the number of substructures in the stream as much as practical. Intermediate supports in streams block the natural flow of the waterway, trap debris, and are subject to scour. Substructure construction in a stream is expensive (especially if cofferdams or dewatering are needed), and environmentally disturbs the stream bottom and water quality. Locate abutments and intermediate supports on shore to minimize dewatering and allow easy access for the Contractor.

The Bridge Designer must balance requirements for structure depth and span length with the constraints of hydraulics, approach grades, structure depth and cost. This requires close coordination with the Hydraulic and Roadway Engineers to ensure that all design requirements are met.

C. ABUTMENT TYPES

Future addition will include information on: Integral abutments
Semi-integral abutments
Expansion abutments
Vertical wall abutments

At integral or semi-integral abutment diaphragms, provide a 5” x 5” concrete fillet at the deck-to-diaphragm interface to facilitate the transfer of axial loads from the deck into the abutment diaphragm.

D. BENT TYPES

Future addition will include information on: Grade separations
Stream crossings

E. AESTHETICS

See Section 3.4 for guidance on aesthetic considerations and their importance in the design process.

3.6 FINAL STRUCTURE PLANS AND SPECIFICATIONS

The primary purpose for preparing final structure plans and special provisions is to communicate the geometric, material, and procedural requirements for the construction of a structure. When preparing final plans, the designer should keep in mind all those who will use these documents during the life of the structure and prepare the plans accordingly. The plan content should reflect the needs of all customers who will use the plans. These include the following:

- During the bidding phase, contractors use the contract documents to prepare their bids. A clear, accurate, and complete set of documents will result in competitive bidding. Well-communicated information reduces contractor uncertainty regarding what is required for different construction elements.
- During the construction phase, several entities use the contract documents to construct and verify construction of the structure.
    - The contractor' forces use the plans and specifications to construct the structure.
    - The Department's construction personnel use them to verify the proper construction of the structure.
    - Fabricators and construction engineers prepare shop drawings and other construction drawings.
    - Material suppliers depend on them to know which products to supply.
- After construction, the plans become part of the bridge inventory maintained by the Structures Division.
    - The bridge management staff identifies and inputs bridge element data into the bridge management software.
    - The bridge inspectors use the plans to inspect each bridge bi-annually and rate the condition of each bridge element.
    - Future designers and contractors will use the plans when modifying, rehabilitating or replacing the bridge.

Specifications describe procedures for award and execution of the contract, how work will be measured and paid, procedures to be followed during execution of the work, and material and testing requirements for items incorporated into the project.

There are three types of specifications:

- **Standard Specifications** – These are the Department's approved standard specifications compiled in book form for use on all Department-advertised projects.

- **Supplemental Specifications** – Includes revisions and additions to the standard specifications since the publishing of the current standard specification book. They are approved by the Standards Committee and FHWA for use on all projects. Supplemental specifications supercede the standard specifications and are incorporated into the standard specification book when a new book is published. The most current version of each standard specification is always available on the Department's web-site.

- **Special Provisions** – Includes revisions and additions to the standard and supplemental specifications for use on specific projects. They may also include project specific requirements (requirements unique to an individual project).

In general, present information that is highly graphical or geometric in nature on plan sheets. Large amounts of information conveyed with text should be assembled in special provisions.

When preparing final bridge plans and specifications, designers need to remember that the completed contract documents have the following order of precedence:

1. Special Provisions
2. Plans
3. Supplemental Specifications
4. Standard Specifications

3.6.1 GOVERNING DESIGN SPECIFICATIONS

Unless specified otherwise within this manual, design all new structures in accordance with the current editions of the following:

1. ***UDOT Bridge Design Manual***

2. **AASHTO *LRFD Bridge Design Specifications***.

3. Design horizontally curved steel bridges in accordance with the AASHTO *Guide Specifications for Horizontally Curved Highway Bridges*.

4. Seismic design of new bridges is in accordance with **MCEER/ATC-49 *Recommended LRFD Guidelines for the Seismic Design of Highway Bridges.*** See Section 6 of this manual for seismic design requirements additional to MCEER/ATC-49.

5. Design bridges that carry railroad traffic according to the current **AREMA *Manual for Railway Engineering*** for the live load specified by the railroad (either UPRR or UTA). Design bridges that carry or cross railroads to meet any additional requirements of the railroad owner. Where requirements differ between different specifications, the more restrictive requirement governs.

6. For bridge widening and rehabilitation projects where the existing bridge was designed using the AASHTO *Standard Specifications for Highway Bridges*, the current version of that specification may be used for the widening and rehabilitation design with the approval of the UDOT Deputy Bridge Engineer for Design.

7. In all cases, prepare structure designs and plans in compliance with the UDOT Structures Design Quality Plan in Section 2 of this manual.

The UDOT Deputy Bridge Engineer for Design approves any exceptions to these requirements.

Before beginning the final design, the designer should review the plans and documents prepared during the preliminary design. These documents include:

- Situation & Layout plans
- Bridge Type Selection Report
- Preliminary Seismic Strategy Report
- Environmental Document. Check for any structure-related environmental requirements and commitments

When reviewing preliminary plans, pay particular attention to geometry and utilities. Check the bridge layout, comparing it to the current roadway geometry.

Further information about the detailing, content and organization of final bridge plans is included in Section 15 – Detailing Practice and *Guidelines for the Preparation of Structure Plans*.

3.6.2 BRIDGE SUPERSTRUCTURE

A. FRAMING

Space beams and girders so that moments in exterior girders will not be larger than moments in interior girders.

Provide a minimum distance between the girder flange or bearing edge and the inside wingwall face of 6-inches. Maintain at least 12-inches between the flange edge and the edge of deck slab.

B. DIAPHRAGMS AND CROSS-FRAMES

The typical bridge type in Utah is a multi-girder system utilizing structural steel or precast prestressed concrete I-girders. Diaphragms and cross-frames are integral elements of these bridge types. They serve a number of functions:

- They provide compression flange bracing during bridge erection and construction.
- They increase lateral load distribution between girders (more beams or girders participate in carrying live loads). This allows the superstructure to resist loads as a system.
- They provide a load path for lateral loads to be carried from the deck to the bearings.
- In curved steel girder superstructure systems, they are primary load carrying members that transfer torsional loads between the girders.
- They assist in transferring lateral seismic loads from the superstructure to the substructure at supports.

(1) Diaphragms on Prestressed Concrete Girder Bridges:

For precast prestressed concrete girder bridges, diaphragms of cast-in-place construction using prestressed or non-prestressed reinforcement are required at span ends. Concrete intermediate diaphragms are not required in spans up to 40 feet; are required at mid-span for spans above 40 feet and to 80 feet; and are required at span third points for spans above 80 feet.

(2) Diaphragms and Cross-Frames on Structural Steel Plate Girder Bridges:

Use cross-frames on structural steel plate girder bridges that are appropriate for the girder depth and spacing. The maximum cross-frame spacing is as required by design, but not to exceed 50 ft.

In all cases, the designer is responsible to verify that the cross-frames and diaphragms selected for use on the bridge will function as designed. For example, X-shaped cross-frames on bridges with wide girder spacing and shallow girder depths or deep girders and small girder spacing may not function effectively. K-frame type diaphragms are recommended for wide girder spacings. (Maybe develop some type of criteria for cross-frame selection based upon span/depth ratio.)

The following are general criteria for selecting cross-frame and diaphragms:
- For girder depths less than 48-inches, use a channel section that is at least two-thirds the depth of the girder.
- For girder depths of 48-inches or greater, use X-frame or K-frame cross-frames for intermediate cross-frames.
- Other diaphragm types may be used when it is demonstrated that they will effectively meet design requirements.
- At supports other than integral abutments, design the diaphragms to transfer the large lateral seismic forces from the superstructure to the substructure. Full-depth plate diaphragms should be considered in these cases (for multi-span bridges?).

C. GRAFFITI PROTECTION

For graffiti protection, provide flange guards on all steel and concrete exterior girders that are accessible without a ladder to prevent pedestrian access along the exterior girders.
- Install steel plate flange guards to exterior steel plate girders where necessary.
- Provide concrete guard blocks to the tops of exterior concrete girder bottom flanges flatter than 45 degrees.
- Locate flange guards to prevent unauthorized access to exterior girder bottom flange. Typically, this will require a 10-foot long plate beginning approximately 10 feet from the abutment as shown in the UDOT Structures standard detail. If this typical layout does not prevent access, adjust the flange guard size and location until access is prevented.

D. EXPANSION AND CONTRACTION

Design all bridges for moderate climate temperature range as defined in AASHTO LRFD 3.12.

Where possible, avoid or minimize expansion joints. Except in special cases, construct bridges up to approximately 360 ft in length without expansion joints. Integral or semi-integral abutments are the preferred type in these cases. Special cases that may require adding one or more expansion joints are bridges with skews greater than 30 degrees, bridges located on sharp curves, and bridges that require dynamic isolation.

Use only strip seal, modular or steel finger joints. In the design and location of joints, provide for maintenance accessibility and future replacement. Do not use aluminum joints. Design modular joints for high-cycle fatigue loading.

When deciding which of two abutments should have an expansion joint, choose the one with the higher elevation.

E. BRIDGE DRAINAGE

Design bridge deck drainage to comply with the UDOT Roadway Drainage Manual and Subsection 2.6.6 of the AASHTO *LRFD Bridge Design Specifications*, except as modified in this manual. Subsection 2.6.6 includes criteria for type, size, number and location of deck drains and handling the discharge from deck drains.

Provide a longitudinal gradient of at least 0.5% on all bridges to facilitate drainage. Avoid zero gradients and sag vertical curves. When preparing final plans, evaluate deck elevations for sags in profiles and superelevation transitions that would create low spots or very flat areas in the bridge deck. When a deck drain cannot be provided at a low spot, adjust the profile or superelevation to move the low spot off of the bridge or to a location where a deck drain can be provided.

.

When designing the bridge drainage system, consider the following:

- Design the bridge deck drainage system to be compatible with the structural reinforcement, components, and aesthetics of the bridge.
- Coordinate the locations of deck drains with the Hydraulics Engineer consistent with UDOT drainage spread requirements.
- Minimize the number of deck drains while meeting hydraulic requirements.
- Capture drainage before it crosses any deck expansion joint.
- Locate deck drains so that outfall does not drop water on traffic lanes or shoulders. This may require adjusting the location of expansion joints when not placed at supports.
- Position the deck drainage outfalls to avoid corrosion of bridge structural members, erosion of embankments, and splashing of moving traffic and sidewalk areas below the bridge.

- Design and construct downspouts with galvanized steel pipe, a minimum diameter of 8-inches, and a minimum wall thickness of 1/8th inch. Provide cleanouts for downspout systems.
- Design grates and frames for deck and approach slab drains in accordance with the following:
  - Use grates and frames that are structural carbon steel conforming to AASHTO M-270 Grade 36 and are hot-dip galvanized after fabrication in accordance with AASHTO M-111.
  - Design for HL-93 live load.
  - Design inlets located on the interstate mainline and ramps with standard grates. Inlets located elsewhere must be designed with bicycle-safe grates.
- Intercept pavement drainage at both ends of bridges before it crosses the approach slab-to-pavement joint. Place drains upstream of the joint.

F. APPROACH SLABS:

At the end of each bridge, provide an approach slab that is at least 25 feet long (measured along the control line of the bridge), is the same width as the bridge deck, and extends over the abutment wingwalls. Make allowance for settlement between the approach slab and wingwall by providing a minimum 5-inch gap between the top of the wingwall and the approach slab.

Provide for expansion and contraction at the approach slab to pavement interface. Use a sleeper slab and a joint type that accommodates the maximum anticipated movement. For skews at the approach slab to pavement interface greater than 20 degrees, provide for a stepped joint or other means of preventing lateral movement of the approach slab due to expansion and contraction. When a stepped joint is used, match step widths to those defined by Standard Drawing PV-2.

Asphalt pavement.

3.6.3 BRIDGE SUBSTRUCTURE

A. BRIDGE REDUNDANCY

Design bridges to minimize the risk of catastrophic collapse by using redundant supporting elements (columns and girders).

For substructure design:

Use one column minimum for roadways 40 feet wide and under.
Use two columns minimum for roadways over 40 feet to 60 feet.
Use three columns minimum for roadways over 60 feet.
Provide collision protection or design for collision loads for piers with one or two columns.

For superstructure design:

Use three girders (webs) minimum for roadways 32 feet and under.

Use four girders (webs) minimum for roadways over 32 feet.

Note: Any deviation from the above guidelines requires written approval from the Deputy Bridge Engineer for Design. (This section comes from WSDOT Manual)

B. HYDRAULIC DESIGN

(1) Scour Design

Design and analyze bridges for scour according to the current Manual of Instruction – Roadway Drainage and HEC-18, *Evaluating Scour at Bridges*. Compute scour using a methodology and software approved by the Department. Protect abutments with riprap according to HEC-18.

Design bridge foundations for scour effects in addition to any scour mitigation measures provided at the bridge site.

- Design bridge foundations to extend a sufficient depth below the design scour depth to carry design loads and remain stable.
- Design the bridge foundation to function and remain stable under the scoured condition. For example, if the scour depth would expose piles or drilled shafts, evaluate the piles or drilled shafts as freestanding columns for the exposed depth. Ensure proper embedment of the piles / caissons beyond the design scour depth. [Note that drilled shaft design is more critical because total depth is much shorter than driven piles, caisson is formed only by the drilled hole, and uses Class A concrete.]

(2) Headwalls for Culverts

- Provide concrete headwalls on all culverts 36-inches and greater. Pipes less than 36-inches in diameter will not typically require concrete headwalls.

3.6.4 CONSTRUCTIBILITY

See AASHTO *LRFD Bridge Design Specifications*, Subsection 2.5.3.

3.6.5 INSPECTION AND MAINTENANCE ACCESS

Make all bridge superstructures, expansion joints, backwalls, enclosed compartments, and bearings accessible for long-term inspection by arms-length direct viewing. Make expansion joints accessible for direct viewing from the underside of the joint. For expansion joints at abutments, provide inspector access between the end diaphragm and the backwall to allow inspection of the backwall and the underside of the expansion joint by arms-length direct viewing. Make open-framed superstructures accessible with walkways or ladders, or by use of a snooper truck

Box girders with an inside depth of 5 feet or more require access through the box girder for interior inspection. In all box girders, provide an opening that is at least 3 feet by 3 feet, has a hinged metal door that swings out from the box girder, and has a removal bolt for locking. Minimize the weight of the door to facilitate opening by inspection personnel. Where required, provide a method of ladder support for inspection access.

3.6.6 SERVICEABILITY

Comply with the serviceability requirements specified in Subsection 2.5.2 of the AASHTO *LRFD Bridge Design Specifications*.

Design areas around bearing seats and under deck expansion joints to facilitate jacking, cleaning, repair, and replacement of bearings and expansion joints. Design applicable structure elements (girders, supports, etc.) for the jacking forces and show jacking points on the plans.

Avoid inaccessible cavities and corners. Avoid or make secure cavities that may invite human or animal inhabitants.

3.6.7 SECURITY-RELATED REQUIREMENTS

Prevent public access to closed areas such as between full-height concrete diaphragms and backwalls on seat type abutments. Use a chain link type fence between the exterior girders and cheek walls with an access gate that has a removal bolt for locking. Do not inhibit the normal expansion and contraction movement of the structure with the detail used.

3.6.8 UTILITIES ON BRIDGES

Do not place utilities on structures unless no reasonable alternative exists. Utilities placed on structures require the approval of the Region Director or his authorized representative and a Utah-licensed Professional Engineer. If utilities must be placed on a structure, hide them from view. Attaching utilities to the visible exterior of the superstructure is not permitted.

Attachment of natural gas utility lines will not be permitted to bridge structures that carry or cross vehicular or pedestrian traffic.

Locate trenching in the vicinity of existing piers or abutments a sufficient distance from footings to prevent undercutting of existing footings or to prevent disturbing foundation soils for future foundations.

When utilities must be placed on a structure, place them as follows:

1. All approved utilities require individual sleeved casings, conduits or ducts as appropriate.
2. Conceal utilities from view (as much as possible).
3. Typically place utilities in the first interior bay.
4. Lay out all utility pipes, etc. on a straight line for the full length of the bridge structure.
5. Place all utilities that carry liquids inside a casing that extends the entire length of the structure for a distance of 10 ft beyond the ends of the approach slabs. When carrying pressurized utilities, design the casing to carry full service pressure so as to provide a satisfactory containment in case the utility is damaged or leaks.
6. Adequately provide for all situations where pipes pass through abutment walls, diaphragms and other structural members.
7. Paint visible pipes and pipe sleeves to match the color of adjacent structural members.
8. Adequately attach utility supports to girder webs. Use roller or cradle type supports that adequately support the pipe, sleeve or conduit and that accommodates longitudinal thermal expansion and contraction.
9. Support bracket details and attachments for all utilities require Structures Division approval.
10. Manholes or access openings for utilities will not be permitted in bridge decks, webs, bottom slabs or abutment diaphragms.

Refer to Administrative Rule R930-6, "Accommodation of Utilities and the Control and Protection of State Highway Rights of Way" for guidance on attaching utilities to bridge structures. This document is available on the UDOT website at the following link:

http://www.udot.utah.gov/index.php/m=c/tid=423/item=3825/d=full/type=1

3.6.9 BRIDGE REPLACEMENT

[Future Addition]

3.6.10 BRIDGE WIDENINGS

[Future Addition]

3.6.11 BRIDGE REHABILITATION

[Future Addition]

3.6.12 TEMPORARY BRIDGES AND WIDENINGS

Design temporary structures and construction falsework, forms, shoring, etc. in accordance with the AASHTO *LRFD Construction Specifications*, Section 3 – Temporary Works.

3.6.13 RETAINING WALLS

Design all retaining walls in accordance with the current version of the AASHTO *LRFD Bridge Design Specifications* – Section 11.

Provide a minimum 15 feet of generally level terrain between the wall face and the Right of Way line for maintenance access. Where 15 feet of level terrain is not available between the wall and ROW line, consult with the Project Manager for guidance on whether to locate the retaining wall adjacent to the ROW line.

Where access is open to the public, provide a pedestrian railing or six-foot fence at the top of the wall.

Provide a minimum clear distance of 3.5 feet between the nearest wall face and the abutment.

Refer to Subsection 14.3 of this manual for approved wall systems and additional retaining wall design criteria.

3.6.14 NOISE WALLS

Design noise walls in accordance with AASHTO *Guide Specifications for Structural Design of Sound Walls*. Standard details for precast concrete post and panel noise walls are provided in UDOT Standard Drawings SW-2, SW-3A, and SW-3B. Details for noise walls that retain a limited height of fill are provide in SW-4A and SW-4B. The Deputy Bridge Engineer for Design must approve any alternate noise wall types prior to incorporation into any project.

All noise walls require textured surfaces on all exposed faces of the panel.

When a noise wall is placed behind a roadway barrier, provide a minimum distance of 5 feet between the barrier and the noise wall for snow storage. The minimum offset dimension may vary depending on project-specific requirements. For the specific offset dimension, consult with the Project Manager.

3.6.15 Overhead Sign Structures

Design structural supports for overhead signs in compliance with the current addition of the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*.

Use galvanized structural tubing and concrete drilled shaft foundations for overhead sign structures. Orient overhead sign structures at right angles (within 10 degrees) to approaching traffic.

Locate overhead sign foundations a minimum distance of 1.2 times the clear zone from the traveled way or protect it with roadside barrier.

Provide a minimum vertical clearance of 17’-6” from the highest point of the road surface to the bottom of any sign panel.

Do not mount signs on bridges unless no reasonable alternative exists. The mounting of any signs on bridges requires the approval of the Deputy Bridge Engineer for Design. If bridge-mounted signs are required, align signs parallel to the bridge for skew angles of 10 degrees or less. Otherwise, align the signs perpendicular to the traveling lanes underneath. Sign panels should not extend above top of parapet or below bottom of girder.

Refer to Section 14.2 for additional design requirements.

3.7 Design Reports

3.7.1 Bridge Type Selection

A Bridge Type Selection Report will be prepared by the Designer and submitted to the UDOT Deputy Bridge Engineer for Design prior to approval of the Situation & Layout Sheet. The Bridge Type Selection Report is a one-to-three page report that outlines the bridge types considered and includes the following:

- A site description including the important characteristics of the project, design constraints, and environmental requirements.
- The advantages and disadvantages of the bridge types evaluated
- Preliminary costs of the bridge types evaluated (minimum of two bridge types)
- Bridge type recommendation

To determine the preferred structural alternative, the designer should:

- List design constraints, environmental commitments and requirements.
- Develop a list of all feasible alternatives. At this stage, the range of alternatives should be kept wide open. Brainstorming with supervisors and other engineers can provide new and innovative solutions.
- Eliminate the least desirable alternatives by applying the constraints of the project. Question and document the assumptions of any restrictions and constraints. There should be no more than four alternatives at the end of this step.
- Perform preliminary design calculations for unusual or unique structural problems to verify that the remaining alternatives are feasible.
- Compare the advantages, disadvantages, and costs of the remaining alternatives to determine the preferred alternative(s).
- Visit the project site (preferably with the Project Manager) to verify the applicability of the selected alternatives.

3.7.2 BRIDGE SEISMIC STRATEGY

The design of each bridge requires the preparation of a Seismic Strategy Report. A preliminary report is included with the Situation and Layout approval submittal. An updated report is submitted with the 60% Review submittal. The Final Seismic Strategy Report will be submitted with the Final Design Review submittal.

The Seismic Strategy Report includes a listing of bridge specific criteria such as bridge importance, seismic performance goals, and earthquake magnitude. It describes the design strategy for resisting the design seismic event. Include descriptions of expected damage, the locations of plastic hinging, the redistribution of forces, the mobilization of backfills, and the function of bearings, as appropriate.

3.7.3 BRIDGE LOAD RATING

FHWA requires that all bridges be load rated. The designer is responsible to load rate all new bridges using methods described in the current version of the AASHTO *Guide Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*. The final inventory load rating shall meet or exceed a Load Rating Factor (RF) of 1.0, based upon the specified AASHTO or UDOT load rating vehicle. The Designer calculates both inventory and operating ratings.

The Load Rating Report is submitted with the Final Design Submittal. It provides a summary of the bridge load ratings of the completed design and the supporting calculations. Include both operating and inventory ratings in the load rating summary. The supporting calculations for the Bridge Load Rating Report are formatted the same as the Bridge Design Calculations.

3.7.4 BRIDGE MAINTENANCE PLAN

Provide a Bridge Maintenance Plan for each unique, non-traditional bridge type used.

- Describe routine maintenance procedures as well as items specific to all components of the bridge type.
- List and describe any unique aspects of the structural elements that are used in the bridge. For example, a post-tensioned deck slab cannot be removed in whole or in part without consulting a structural designer.
- Include a detailed list of all expected maintenance and rehabilitation work, and the number of times each procedure is to be anticipated over the 75-year structure life (itemized by the year in which the procedure is to be performed). Make the items on this maintenance list the same as those that would be used for life cycle costs.

APPENDIX

[Future Additions]

Appendix 3A – Design Aids
Information Required to Design Structure
Situation & Layout Checklist

Appendix 3B – Sample Plans